METHOD AND APPARATUS FOR FILLING A MASK WITH SOLDER PASTE

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of USSN 09/962,007 filed 9/24/01 (status: Issue Fee paid 6/9/2003, hereinafter "Parent Application").

TECHNICAL FIELD OF THE INVENTION

The invention relates to techniques for filling (printing) cells (openings) of masks (stencils) with solder paste, such as masks which are used in conjunction with techniques for forming solder balls (bumps) on substrates which are electronic components, such as dies, wafers, packages, etc. .

BACKGROUND OF THE INVENTION

A number of patents describe techniques for forming solder balls (also referred to as "bumps") on substrates which are electronic components, such as forming arrays of solder balls on pads of integrated circuit (IC) chips which are individual components or one of several components on a semiconductor wafer. For ICs, the solder balls tend to be relatively small, such as 4 mils. Another example of an electronic component having solder balls is a ball grid array (BGA) package. For BGA packages, the solder balls tend to be relatively large, such as 25 mils. In some cases, solder balls may be formed on an interconnection substrate in addition to or rather than on the electronic component being attached thereto.

As used herein, the term "solder ball" refers to a substantially spherical or hemispherical mass (bump) of solder (e.g., lead-tin solder) resident on a substrate (e.g., electronic component), suitable for being re-flowed to join the electronic component to another electronic component. A "large solder ball" is a solder ball having a diameter of greater than 20 mils (>0.020 inches). A "small solder ball" is a solder ball having a diameter of up to 20 mils (<= 0.20 inches).

As used herein, the term "electronic component" includes any circuitized substrate, typically having "pads", including but not limited to integrated circuit (IC) chips (including prior to or after singulation from a semiconductor wafer), printed circuit boards, polyimide interconnection

elements, ceramic substrates, and the like. As used herein, a "substrate" is an electronic component having a nominally flat surface upon which it is desirable to form solder balls to effect electrical connections to another electronic component.

Various technique for ball bumping substrates include using a mask (stencil) having cells (apertures, openings), filling the cells with solder paste, then reflowing the solder paste. Typically, the stencil is placed on a substrate having pads, with the filled mask openings aligned with the pads, then reflowing the solder paste. After reflow, the mask is removed.

The mask may be filled either after being placed on the substrate, or before (off-line). Typically, the filling process involves dispensing a relatively large amount (much more than is needed to fill the cells of the mask), of solder paste onto the stencil, then moving (advancing) a screening blade (sometimes called a "doctor blade") across the mask surface in a manner to force solder paste into the cell openings. For purposes of the present discussion, solder paste is considered to be a "viscous material".

Conventional solder paste typically contains tiny particles of solder material (lead/tin), in a matrix of flux, and comprises about <u>30%</u> (by volume) solid material. A typical solder paste contains particles of lead/tin solder, in a matrix of flux, with the following proportions: <u>80%</u> (by weight) solid material (e.g., particles of lead/tin solder), and <u>20%</u> (by weight) flux (including volatiles). In terms of relative volume percentages, the same typical solder paste may contain approximately <u>55%</u> (by volume) of solid material (metal) and <u>45%</u> (by volume) of flux. It should be understood that the present invention is not limited to a particular solder paste formulation.

US Patent No. 5,988,487 describes captured-cell solder printing and reflow methods. A screening stencil is laid over the surface of the substrate and solder paste material is deposited into the stencil's apertures with a screening blade. The stencil is placed in such a manner that each of its apertures is positioned over a substrate pad upon which a solder bump is to be formed. Next, a flat pressure plate is laid over the exposed top surface of the stencil, which creates a fully enclosed (or "captured") cell of solder material within each stencil aperture. Then, with the stencil and plate

remaining in place on top of the substrate, the substrate is heated to a temperature sufficient to reflow the solder material. After reflow, the substrate is cooled, and the pressure plate and stencil are thereafter removed, leaving solder bumps on the substrate pads.

US Patent No. 6,293,456 describes various methods for forming solder balls on substrates. Mask configurations, methods or mounting the masks, and solder material compositions are described.

Parent Application No. 09/962,007 filed 9/24/01 (status: issue fee paid) describes techniques for ball bumping substrates, particularly wafers. A number of masks (e.g., 110) are shown therein.

The present invention is particularly useful in conjunction with the ball-bumping techniques described above. The following patents are cited as techniques which may also benefit from the present invention. It should be understood that the present invention is not limited to the specific exemplary ball-bumping techniques mentioned herein.

US Patent No. 5,539,153 ("Hewlett Packard") discloses method of bumping substrates by contained paste deposition. The solder is applied through stencil/mask and paste method; the mask, however, remains attached to the substrate during reflow.

US Patent No. 5,492,266 ("IBM-1") discloses fine pitch solder deposits on printed circuit board process and product.

US Patent No. 5,658,827 ("IBM-2") discloses method for forming solder balls on a substrate. Solder balls are formed by squeegeeing solder paste through apertures in a fixture into contact with pads on a substrate, and heating the fixture, paste and substrate to reflow the solder paste into solder balls.

Consistency in the size (e.g., height/volume) of the solder ball contacts is a critical factor. For a given solder paste, the size of the solder ball is determined principally by the size of the mask cells, and how well the cells are filled. Desirably, each and every cell is equally filled to full capacity,

with no voids. This requires a technique for consistently filling the cells of a mask. A solder ball from a partially filled cell will be smaller than a solder ball from a fully filled cell. If one or more of the resulting solder balls are significantly shorter than others (usually due to an insufficient amount of solder paste deposited on one or more conductive pads prior to contact formation) it is likely that these smaller (shorter) contacts may completely miss their mating contact pads (e.g., on the circuit board) and will fail to form an electrical connection between the ball-bumped electronic component and the underlying interconnection substrate (e.g., printed circuit board). Hence, quality control is critical, since proper electrical connections between the electronic component and the underlying substrate to which it is assembled are formed only if each and every one of the solder ball contacts reflows correctly and wets its associated conductive pad on the underlying substrate. It can be very expensive to inspect all the bumps (solder balls), and time consuming. Defective assemblies of electronic components to interconnection substrates can be difficult or impossible to repair after assembly if connections are not properly formed. Even prior to assembly, the correction of improperly formed solder balls on the exterior of an electronic component such as a BGA package can be very difficult and involves, initially, careful quality control inspection of the ball bumps prior to assembly of the packaged device to a substrate.

Standard print heads for filling cells of masks with solder paste typically use hydraulic pressure to force solder paste into the mask cells, then a print blade scrapes off excess solder paste. Some of the problems associated with this procedure are:

a. When filling a mask which is on a substrate (electronic component), such as has been described above, if a poor seal exists between the mask and the substrate (due to irregular surface topology), solder can be pumped (or leak) under the mask, onto an adjacent area of the substrate.

b. A resilient blade, such as of Permalex (tm), may be used, and the blade (the thickness or profile of which is typically larger than the cross-dimension of the cell) may form a seal with the cell, thereby trapping air (rather than solder paste) in the cell.

c. It has been found that printing a mask normally takes multiple passes of the blade to ensure complete cell filling, without "gouging".

d. It is important that the surface of the mask be clean (free of excess solder paste) after printing.

In conventional mask filling techniques, the solder paste wave or extra paste at printing is pushed out in front of the print blade. This flood causes the paste to wet the top surface of the cell sealing the air inside and creates "printing voids". This problem is exacerbated with the more fluid (e.g., <85% weight %) pastes. Permalex (tm) blades are known, and they typically avoid gouging. Nevertheless, often, it takes 6 or more passes to fill small cells. When multiple passes are made, it is believed that the solder paste wets the mask surfaces and removes some of the trapped air each time filling the cell just a bit more each print stroke.

BRIEF DISCLOSURE (SUMMARY) OF THE INVENTION

It is an object of the invention to provide an improved mask-filling technique, such as in conjunction with forming solder balls on electronic components.

According to the invention, a method is provided for filling (printing) cells of a mask with a solder paste as a prelude to ball bumping an electronic component. Generally, with a first (flood) blade disposed a distance above a top surface of the mask, and with a glob of solder paste (viscous) material in front of the first blade, the first blade is advanced across the surface of the mask. This is followed by a second (cleaning) blade which is in contact with the surface of the mask. The second blade advances across the surface of the mask to remove residual solder paste from the surface of the mask. The distance between the first blade and the mask is on the order of a few (2-5) times the average particle size in the solder paste. The first blade may be plastic. The second blade is preferably non-compliant, such as metal.

According to a feature of the invention, the first blade is generally rectangular in cross-section, having a leading surface, a trailing which is generally parallel to the leading surface, and a side edge which is generally perpendicular to the leading and trailing surfaces and which, in use, is disposed opposing the mask, wherein the side edge is chamfered (beveled) so as to present a sloping surface for pushing the solder paste down into the cells of the mask when the first blade is moved across the mask.

According to a feature of the invention, a sequence of masks (two or more masks, in sequence) can be printed by positioning a first mask between a first print landing areas and a second print landing area. With a first set of blades, starting at the first landing area, moving across the mask to the second parking area to fill the cells of the first mask, then retracting the first set of blades. Then, with a second set of blades, starting at the second landing area, moving across the mask to the first landing area to fill the cells of a second mask.

Benefits of the present invention include:

a. the problem of solder being pumped under the mask can be avoided.

b. the problem of trapping air in the cell can be avoided.

c. a mask can successfully be printed in a single (one) pass.

d. the surface of the printed mask will be free of excess solder paste after printing.

The "off-wafer" printing of the present invention mainly used to ensure that the cell volume is substantially exactly the same for each wafer. Normally, as wafer topography changes it will hang the mask up and allow leakage under the mask, or at least change cell volume. For 100 micron balls a 30% change can be present. The off-wafer printing of the present invention can achieve <2 micron variation. The largest print volume variation comes from gouging paste out of the cell at print. This can result in a 40% loss in wet paste and is a primary concern this is the main reason that the invention use two blades - one to overfill the cells and the other (which may be Permalex) to remove excess solder paste (scrape the cell even with mask top surface.) Also very important with cell soldering is to have the top surface of the mask cleared of solder paste residue for "capturing "of the cell (see, e.g., US Patent No. 5,988,487 mentioned above).

Other objects, features and advantages of the invention will become apparent in light of the following description thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will be made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. The drawings are intended to be illustrative, not limiting. The cross-sectional views, if any, presented herein may be in the form of "slices", or "near-sighted" cross-sectional views, omitting certain background lines which would otherwise be visible in a true cross-sectional view, for illustrative clarity.

Figure 1 is an exploded cross-sectional view of a method and apparatus for forming solder balls on substrates, such as is disclosed in USP 5,988,487.

Figure 1A is an enlarged (magnified) view of the substrate (102) shown in **Figure 1**, after completion of ball bumping.

Figure 2 is a side, cross-sectional view of a technique for applying solder paste to cells in a mask, according to the invention. This drawing corresponds to Figure 12 of the Parent Application.

Figure 3 is a side, cross-sectional view of a set of blades, such as those shown in Figure 2, according to the invention.

Figure 4 is a schematic side view of two sets of blades, such as those shown in Figure 2, according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates a technique 100 for forming solder balls on a surface of a substrate 102, such as is set forth in U.S. Patent No. 5,988,487. The substrate 102 has number of pads 104 on its top (as viewed) surface. The pads 104 are typically arranged in an array, having a pitch (center-to-center spacing from one another). The substrate 102 is disposed atop a heater stage 106. A mask (stencil) 110 is provided. The mask 110 is a thin planar sheet of relatively stiff material, such as molybdenum, having a plurality of openings (cells) 112, each corresponding to a pad 104 whereupon it is desired to form a solder ball on the substrate 102. The mask 110 is placed on the top (as viewed) surface of the substrate 102 with the cells 112 aligned over the pads 104. The cells 112 in the mask 110 are filled with solder material 114. This is done in any suitable manner such as by smearing solder material on the top (as viewed) surface of the mask 110 and squeegeeing the solder material 114 into the cells 112 of the mask 110. Squeegeeing is typically a multi-pass process.

The cells 112 in the mask 110 may be filled with solder paste prior to placing the mask 110 on the top surface of the substrate, in which case the solder-paste-filled cells 112 would be aligned over the pads 104.

A pressure plate 120 is disposed onto the top (as viewed) surface of the mask 110. This holds the mask 110 down onto the substrate 102, and the substrate 102 down onto the heater stage 106. This

also closes off the cells 112 ("captured cell"). The heater stage 106 is heated up, typically gradually, to a temperature sufficient to cause the solder material in the cells 112 to melt (reflow). When the solder material melts, the individual solder particles will merge (flow) together and, due to surface tension, will try to form (and, typically, will form) a sphere. When the solder material re-solidifies, it assumes a general spherical or hemispherical shape. The mask 110 is then removed from the substrate 102.

Figure 1A is an enlarged (magnified) view of the substrate 102 shown in **Figure 1**, after completion of ball bumping. Herein it can be observed that the solder balls 130 are generally spherical, have a diameter "D" and have a height "H".

When printing, for example, on the surface of an integrated circuit wafer, it must be appreciated that the surface of the wafer is often not very flat, topologically speaking. And this irregular topology can lead to variations in the effective overall volume of a cell being filled with solder paste. Also, as mentioned above, when printing on an irregular surface, solder paste can ooze out under the mask, creating subsequent problems during reflow. As a general proposition, any variations in the process, from cell-to-cell, are simply not desirable. Hence, printing on a known flat surface (KFS) - such as the surface of the heater stage (e.g., 106) - is preferred. Also, by printing "off-line", the wafer is spared from the sometimes excessive forces required to get a good print (effective cell filling). we didn't mention the excessive force problem above.

According to an aspect of the invention, it is generally preferred to print "off-line" - in other words, with the mask on a smooth surface without irregularities, rather than on the surface of an electronic component (e.g., substrate102). This is for purposes of (i) uniformity and (ii) to avoid damaging an underlying component.

Off-wafer printing is good for three reasons:

1: Low force

2. Excellent cell volume control

3. Finished solder void control – when the solder paste wets to the pad of a part to be bumped this flux can be trapped during the reflow (solder voids). With off wafer printing the solder

paste is not wetted to the pad, the ball is sphereized in the mask and only contacts the pad after liquefied this avoids flux trapped voids . No other process offers this void avoidance.

Printing off-line is illustrated, for example, in Figure 4 of the aforementioned Parent Application which is a schematic diagram of a machine for ball bumping substrates including a print station 414, which may be a flat, non-wettable surface for off-wafer filling of the cells of the mask with solder material.

The flat surface is non-wettable from the solder material's perspective. Suitable materials are Teflon (tm) coatings and chrome. The flat surface should not only be free from surface topology and defects such as scratches or dings and dents, but will remain flat during heating at high rates. Heat differences coupled with the materials expansion properties may result in warpage during heating.

Figure 2 illustrates an embodiment of the mask-filling technique of the present invention.

It should be understood that the technique is not limited to filling masks for the purpose of ball bumping electronic components, and has more general applicability to any number of printing (mask filling) processes, whether ball bumping or otherwise. It should therefore also be understood that the present invention is not limited to filling masks with any particular solder paste or, for that matter, with solder paste at all. The technique is well-suited to filling the cells of the mask with any material having a viscosity in the range of 20 kcps - 300 kcps (kilocentipoise).

As shown in the figure, a quantity (blob, glob, mass) of solder paste 202 is disposed on the surface of the mask 210 (compare 110). The mask 210 is shown as being disposed on a suitable support surface 208 (compare 106, or 414 of Parent Application). The support surface 208 may be a wafer, for printing with the mask 210 already disposed on a wafer (compare 102), if so desired. Or, the support surface 208 may be any non-wettable surface for off-line filling of the mask.

The mask 210 has a plurality of cells 234 (compare 112) which may be arranged in an array. The cells 234 may be round, square or the like. The mask has a thickness, typically 3 mils. The cells are preferably, but not necessarily, uniform in size, hence volume. For example, a square cell may have a cross-dimension of 6 mils.

A first "print" (or "flood") blade 220, such as a rubber blade made of 90 durometer ULON (tm), is brought to a distance of a few mils (e.g., 5 - 7 mils) from (above) the surface of the mask 210. The blade 220 is advanced in the direction of the arrow 222. As the blade 220 advances, the cells 234 become filled with solder paste 202 (compare 114). It is preferred that the blade 220 not contact the mask, and not drag across the mask. Because the blade 220 is spaced from the mask 210, there will inevitably be an amount of excess solder paste on the surface of the mask behind (to the left of, as illustrated) the blade 220.

Since the blade 220 is not in contact with the mask 210, the contact pressure is essentially zero. This can be important when the mask 210 is supported on a delicate electronic component that might be adversely affected by pressure.

The gap (spacing) between the blade 220 and the surface of the mask 210 is generally dependent upon the size of particles (not illustrated) in the solder paste 202. Typically, the gap is 2-5 times the average particle size.

The blade 220 suitably has a thickness of approximately <u>0.250 inches</u>, is spaced approximately <u>5-7 mils</u> from the surface of the mask 210, and is suitably formed of a material ranging from a very hard material such as <u>stainless steel</u> to a relatively soft material such as <u>60 Shore A rubber</u>. A suitable material is Ulon (tm).

Since the principal purpose of the flood blade 220 is simply to push solder paste into the cells, its composition and end-profile (e.g., dull versus pointy) do not matter very much.

Preferably, the flood blade 220 is inclined in the direction of travel, rather than straight up and down (as illustrated) - for example at an angle of 75 degrees (rather than 90 degrees, as illustrated) with respect to the surface of the mask.

A second, "cleaning" blade 230, such as a Permalex (tm) blade by Transition Automation SPK-PLX-1.5-9, is disposed so as to contact the mask 210, and advances in the direction of the arrow 222. In essence, the cleaning blade 230 follows a suitable distance behind the flood blade 220, and performs "clean up" duty. By way of example, the distance between the two blades 220 and 230 is approximately 1" (one inch) which is quite suitable for printing a mask for a 6 or 8 inch wafer. This distance between the blades 220 and 230 should be sufficient to allow room for the accumulation of paste left behind by the flood blade 220.

Since the cleaning blade 230 need not perform a cell-filling function, it can have a low contact force (e.g., 2500 grams) with the surface of the mask 210. As discussed above, a high contact force can be undesirable. And the non-compliance of the blade 230 allows it to clean the surface of the mask without gouging (removing solder paste from) the already-filled cells.

The blade 230 is suitably spring steel or the like, then the tip or printing edge is coated with a polyimide coating, then a final metal coating is deposited. This as claimed by the manufacturer is the common ground between hard steel (no compliance requiring high pressures to obtain complete contact) and soft rubber that deflects into cell volume and gouges (conforms too well)

The blade 230 suitably has a thickness of 0.010 inches, is in contact with the surface of the mask 210, and is suitably formed of a material ranging from a very hard material such as stainless steel to a relatively hard material such as spring steel. The end of the blade 230 in contact with the mask 210 and is specially coated to ensuring good cleaning of the mask surface without gouging solder paste out of the cells.

The flood blade 220 and the cleaning blade 230 may move in unison, or independently from one another. The may both be inclined in the direction of travel. The flood blade 220 is suitably of a

plastic material, and is spaced a distance equivalent to a few (e.g., 2-5) average solder paste particle sizes from the surface of the mask 210. The cleaning blade 230 is suitably of a metal material, and is preferably thicker than the cross-dimension of a cell 234. The flood blade 220 and the cleaning blade 230 are shown out-of-scale (not to scale), vis-a-vis the mask 210, for illustrative clarity.

Therefore, the invention can generally be characterized as comprising using two dissimilar blades to fill cells of a mask (210) with solder paste (202). The first blade (220) is not in contact with the mask, and therefore "overfills" the cells. The second blade (230) follows behind (after, later) the first blade (220) and removes excess solder paste from the surface of the mask. The first blade (220) exerts no direct pressure on the mask. The second blade (230) exerts very little pressure on the surface of the mask. The first blade (220) is of a wide range of materials. The second blade (230) is preferably of a non-compliant material.

A person having ordinary skill in the art to which this invention most nearly pertains will recognize that any suitable mechanical mechanism (e.g., actuators, etc.) can be used to control the movement of the blades (220, 230) across the surface of the mask (210), and that they can be moved in unison with one another, or independently from one another.

The two blades (220, 230), herein considered to be a "set" of blades, can be moved in unison, as discussed above, with the second blade (230) trailing the first (230) and moving in the same direction as the first (220). The technique of the present invention has been found to be reliable for fully filling the cells of a mask, in only one pass. Alternatively, the second blade (230) can be independently moved across the surface of the mask, including in a different direction than the first blade (220) , including making more than one pass across the mask to ensure that the surface of mask is clean.

Figure 3 illustrates an embodiment of a set of blades comprising a first blade 320 (compare 220) and second blade 330 (compare 230) for printing a mask 310 (compare 210). Profiles for the two blades 320 and 330 are described. The flood blade 320 is generally rectangular in cross-section, having a leading edge (surface) 322, a trailing edge (surface) 324 which is generally parallel to the

leading edge, and a side edge (surface) 326 (comprising 326a,b,c) which is generally perpendicular to the leading and trailing edges. In use, the side edge 326 is disposed opposing (facing) the mask 310, but is not in contact with the surface of the mask. (A non-wettable support surface, compare 208, is omitted, for illustrative clarity.)

The side edge 326 is chamfered (beveled) so as to present a sloping surface for pushing the solder paste (202) down into the cells of the mask when the blade 320 is moved (left-to-right in the illustration) across the mask 310. For example, from the trailing edge 324, the side edge 326 has a first area 326a which is flat and perpendicular to the trailing edge 324 (and parallel to the mask 310), followed by a second area 326b which forms approximately a 45-degree angle with the first area 326a, followed by a third area 326c which forms a steeper, approximately 60-degree angle with the first area (or, a shallow, approximately 30-degree angle with respect to the leading edge 322). This "business end" of this blade 320 is shown with a flat area 326a and compound bevel 326b,c at the junction of the side edge 326 and the leading edge 322. The flat area 326a is preferably approximately 75% of the overall blade thickness.

When the blade 320 is moved across a mask, with a glob of solder paste in from of it (see, e.g., Figure 2), the 60-degree area 326c is the first to encounter the older paste (see Figure 2) as the blade moves across the mask. This angle, being less than 90-degrees, starts to push the solder paste down as the blade 330 moves, exerting a mild downward force on the solder paste. (It should be understood that a similar result could be obtained by tilting the entire blade 230 of Figure 2 forward 30-degrees from vertical.) The next, 45-degree area 326b further helps to push the solder paste down into the cell. (With a 30-degree tilted blade, this area would be 15-degrees steeper.) Finally, the flat area 326a forces the solder paste into the cell.

In any case, the flood blade 320 has at least one area which first encounters the solder paste at an angle between flat (parallel to the mask surface) and vertical (perpendicular to the mask surface), to start pushing (directing) the solder paste down into the cells, followed by a substantially flat (parallel to the mask surface) area for finally pushing (forcing) the solder paste into the cells. The

point is to fill (in this case, overfill) the cells of the mask in one pass, without requiring exerting a lot of pressure on the mask (particularly if the mask were atop a delicate electronic component).

Figure 3 also illustrates an embodiment of a cleaning blade 330 (compare 230). As mentioned above, the cleaning blade 330 is preferably formed of a relatively non-compliant material, such as metal. The cleaning blade 330 comes into contact with the mask 310. An end portion 332 of the cleaning blade 320 preferably forms an approximately 45-degree angle with the surface of the mask 310. For example, between 30-degrees and 60-degrees, preferably approximately 45-degrees. The cleaning blade 330 could simply be one flat sheet of metal inclined at said approximately 45-degrees. However, in a set of blades moving in unison across a mask, the cleaning blade 330 needs to "fit" behind the flood blade 320. Therefore, the cleaning blade 330 is suitably bent (folded) so that the angled end portion 332 extends from a base portion 334 which extends substantially parallel to the flood blade 320 (perpendicular to the mask 310). (Here, the end portion 332 is shown at 45 degrees to the surface of the mask. The end portion 332 should be between 30-60 degrees to the surface of the mask. The end portion 332 forms an obtuse angle with the base portion 324.) It has been found that the base portion 334 should be at least 2" (two inches, 5 centimeters) in length for filling a "normal" mask for ball bumping a 6-8 inch wafer. This dimension was determined empirically. The "long" (quasi-cantilevered, compliantly-mounted) mounting of the cleaning blade performs well. It is believed that it creates a bit of compliance, avoiding "chatter" during the process of scraping excess solder paste off of the surface of the mask.

Figure 4 illustrates an arrangement wherein two sets of blades are used to expedite automatic mask printing. The drawing is merely illustrative, and is not to scale. A first set of blades comprises a flood blade 420 (compare 320) and a cleaning blade 430 (compare 330). A second set of blades comprises a flood blade 440 (compare 320) and a cleaning blade 450 (compare 330). A mask 410 (compare 310) is disposed between two print landing areas 450 and 460. (A non-wettable support surface, compare 208, is omitted, for illustrative clarity.)

The first set of blades 420/430 is "parked" on the first print landing area 460. A glob of solder paste (compare 202) is disposed in front of the flood blade 420, on the first print landing area 460.

The first set of blades 420/430 then advances across the mask 410 (from left-to-right, as illustrated), towards the second print landing area 470, to fill the cells of the mask (to "print" the mask). The first set of blades continues to print, until it is entirely beyond the mask, and until the residual solder paste (that portion of the solder paste which did not make it into the cells) that is being pushed forward is on the second print landing area 470. Then the first set of blades 420/430 can be retracted, and repositioned on the first print landing area 460. Meanwhile, the printed mask is taken away, and another, subsequent mask is positioned between the two print landing areas 460 and 470 to be printed. The second set of blades 440/450 is the "mirror image" of the first set of blades, and prints the subsequent mask by pushing the residual solder paste across the mask, from right-to-left (as illustrated). When finished, the residual solder paste that has been pushed forward (to the left) by the second set of blades will be on the first print landing area 460, and the second set of blades will return to its starting position. A subsequent mask can then be printed by the first set of blades pushing this residual solder paste over the subsequent mask onto the second print landing area, etc, so long as there is an adequate supply of residual solder paste. In this manner, certain efficiencies of operation can be achieved.

Although the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character - it being understood that only preferred embodiments have been shown and described, and that all changes and modifications that come within the spirit of the invention are desired to be protected. Undoubtedly, many other "variations" on the "themes" set forth hereinabove will occur to one having ordinary skill in the art to which the present invention most nearly pertains, and such variations are intended to be within the scope of the invention, as disclosed herein.